

August 29, 2004

Via Federal Express and Email

Mr. Warren D. Osterberg
U.S. Department of Transportation
Research and Special Programs Administration
Office of Contracts & Procurement, DMA-30
Room 7104
400 7th St. SW
Washington DC 20590

Dear Warren:

Contract No. DTRS56-03-T-0003
5th Quarterly Status Report (Project #1) - REVISED
Period: April 1, 2004 to June 30, 2004

Enclosed is the revised 5th Quarterly Status Report for the “Improvements to the External Corrosion Direct Assessment Methodology by Incorporating Soils Data” project.

If you have any questions, please contact me at colwell@battelle.org or (614) 424-4528.

Sincerely,

Jeffery A. Colwell
Vice President

cc: James Merritt

Quarterly Status and Progress Report
Improvements to the External Corrosion Direct Assessment
Methodology by Incorporating Soils Data
Agreement DTRS56-03-T-0003
5th Quarterly Status Report - *Revised*
April 1, 2004 to June 30, 2004

Introduction

The subject contract covers two projects: (1) adding soils data to the previously developed external corrosion direct assessment (ECDA) datasets and methodology and (2) developing a quantitative basis for evaluating certain time-dependent threats. Status of the first project is reported here, the second project is reported separately.

PROJECT 1: ECDA SOILS MODEL

Objective

The objective of this project is to add soils data and a soils model to the previously collected external corrosion direct assessment (ECDA) datasets and methodology. This project includes

- working with volunteer pipeline operators as they conduct ECDAs by qualitatively assessing and providing input to the programs,
- collecting soils-related data, and
- modifying an existing soils model, which was developed for stress-corrosion cracking assessments, for ECDA.

General

This project is being conducted in conjunction with an ECDA demonstration project that is separately funded by GTI/PRCI. Some of the work from the demonstration project is reported here for completeness.

Technical Status

This project includes the following tasks:

- Task 1 – Data review. The milestones for this task are a kickoff meeting and completion of the data reviews.
- Task 2 – Contacting pipeline companies. The milestones for this task are a review meeting and completion of a schedule for collection data.
- Task 3 – Data collection. The milestones for this task are additional datasets.
- Task 4 – Data alignment. The milestone for this task is completion of the alignment.

- Task 5 – Development of confidence measures and a soils model. The milestones for this task are a set of confidence measures and a soils model for incorporation into the ECDA methodology.
- Task 6 – Progress reporting. The milestones for this task are the progress reports.
- Task 7 – Final reporting. The milestones for this task are draft and final reports.

The completion of each task represents a payable milestone.

Task 1. Review Prior Data

Status: Completed

As reported previously, this task has been completed.

Task 2. Contact Pipeline Companies

Status: Completed

As reported previously, this task has been completed.

Task 3. Collect Data

The third task represents the largest portion of the work to be conducted by Marr Associates: data collection. Marr Associates is responsible for the data collection efforts, which include soil characterization, topographical, and drainage surveys. Additional data collection may involve repeating prior aboveground measurements.

Status: Completed

The lines that are available to us have been surveyed. Not all the lines that we wanted access to were available because of company work schedules, their crew availability and weather delays. However, there is enough data to complete the analysis. We have tentatively kept sites on the list so that if something changes and we can ultimately do a site analysis before the report data is completed we will add it. The lines are:

- 30" diameter line with asphaltic and tape coatings, rural area, southern/Midwest soils, roughly 50 years old, history of prior corrosion;
- 24" diameter line with coal tar enamel coating, one short replacement section, rural area, Midwest soils, parallel lines, roughly 55 years old, no known history of prior corrosion;
- 30" diameter line with over-the-ditch coal tar coating, rural area, Midwest/southern soil, roughly 50 years old, no known history of prior corrosion;
- 12" diameter with coal tar coating, northern soils with rocky outcroppings, 40+ years old, no known history of prior corrosion;
- 30" diameter with coal tar coating, rocky midwest/northeast soils, details not yet available;
- 30" diameter with coal tar coating, desert area, western soils, 40-50 years old, history of prior corrosion;

- 16" diameter line with coal tar coating, residential area, southern soils, numerous crossings and potential interference issues, possible marshy areas, 55-60 years old, no known history of prior corrosion;
- 16" diameter line with coal tar coating, heavily urbanized area, electrically isolated line segments, numerous crossings, midwest/northern soils, significant interference and stray currents; roughly 30 years old, no known history of prior corrosion;
- 30" diameter with coal tar coating, coastal area, numerous replacements and crossings, 40-50 years old, history of prior corrosion likely;

The data for the lines have been collected and it is currently being modeled.

A review meeting with the company participants was held in Houston on April 21, 2004. The next meeting will be held in August or early September.

The milestones for this task are completion of the data collection process and two review meetings. This task is complete.

The data for the sites listed above is extensive and is being evaluated. However, the data from one site has been abridged and appended here to provide a general idea of how the process was implemented and what type of data was collected.

Task 4. Align Data

Task 4 covers checking and aligning data collected in Task 3 with prior data and data being collected under a complementary ECDA demonstration program. The Task 3 data will be combined with other indirect inspection data to expand the relational model used in the ECDA methodology.

Status: Underway

The data alignment has been very accurate given the above ground measurement tools available today. This has made the population of the model easier than expected.

The milestone for this task is completion of the data alignment, which was scheduled to occur between August 2004 and September 2004.

Task 5. Develop Confidence Measures

Task 5 covers statistically analyzing data from prior programs and from Tasks 2 through 4 and developing quantitative measures of the ability to predict corrosion from aboveground and soils data. This task also includes development of the soils model.

Status: Underway

The deliverable for this task is the development of a soils model for incorporation into the ECDA process. This task was originally scheduled to begin in May 2004, but was started early by

beginning to evaluate correlations that exist in the database. In addition, model development is also underway.

Data mining of the existing database representing 76,000 km of soils data is still being completed and correlations with the sites investigated here are in process. As an example, for one of the sites for Operator E in the companion PRCI program, the detailed analysis indicated that the operator should expect 113 feet of susceptible area for corrosion and 15,114 feet of non-susceptible area.

The confidence measures make use of a qualitative scale based on existing ILI/Soils model data. Presently the model is based on the number of corrosion features per meter, which doesn't take into account the severity of the corrosion or rate of corrosion if it is active. The actual measure could be different for each line because one might want a model that finds corrosion greater than 10%, another might want to find corrosion that would fail B31G. However, for this program the model will provide line segments that could be at risk given the soil conditions there compared to problem areas that have been identified under similar conditions in the past.

Building the external corrosion model

Soil surveys gather the data that is critical for the development of accurate external corrosion models. When used in conjunction with maintenance records, other related DA surveys, and verified using investigative excavations, these models become powerful tools for locating and predicting where these integrity threats will occur on a pipeline.

Marr Associates have created an external corrosion model by aligning soil survey data with ILI data along several valve sections of a pipeline. The valve sections were chosen first based on coating type, as different coatings behave quite differently and therefore require separate models.

The only soil properties considered were drainage, soil type and texture, and topography. This data was then correlated to the ILI data, and the result was corrosion distributions, in number of features per meter for each unique pair of soil properties. An example of the output is shown in the following Table.

ILI-Soil Model Correlation Example

Corrosion Features per meter	Terrain Type			
Drainage Type	A	B	C	Total
A	1	0	10	11
B	1	143	0	144
C	0	8	0	8
Total	2	151	10	163

The results from the correlation tables were then used to create model criteria for this line. For this example an environment with Drainage Type B and Terrain Type B would be considered corrosive. The model could also be modified to account for corrosion severity, corrosion depths, or growth rate instead of the number of features. Different soil properties, coatings, and cathodic

protection could also be accounted for. Basic, easily determined properties were used for the initial model because the model needs to be applied to a broad range of pipeline environments.

By combining data from a number of valve sections, correlations were developed between the number of corrosion features and certain types of soil property combinations. These combinations were then ranked on an arbitrary, qualitative scale.

The soil model is not meant to be used by itself; rather, it is meant to be combined with cathodic protection and coating survey data to help prioritize pipeline segments for investigation. As more soil data is used, the more accurate the model will be.

As data on a specific pipeline is collected through excavations, this information is used to refine the criteria used for that pipeline. Not only does this increase confidence in the model, but this also allows specific corrosion problems such as a poorly applied coating or cathodic protection system problems to be addressed.

Task 6. Progress Reports

This task covers up to seven quarterly progress reports for the project.

Status: Started

The deliverables for this task are quarterly progress reports. This is the fifth report to be completed.

Task 7. Final Report

This task covers preparation of the final project report.

Status: Not Yet Started

The deliverables for this task are a draft and final report.

Payable Milestones

Milestone 3 has been completed and will be invoiced for \$42,688. Previously, Milestones 1 and 2 were completed.

Attachment: Example of Selected Data from Field Report
From One Site in the Program

2.0 Introduction

Marr Associates was retained by PRCI to collect data through the direct examination of a pipeline system for the development of an external corrosion model. During March of 2004, Marr Associates personnel performed direct assessment investigations at two sites selected by Operator E. These sites along the pipeline system were chosen from the results of indirect surveys.

2.1 Project Description

The purpose of the excavation investigation portion of the ECDA Validation Program was to gather data from the direct examination of the pipeline to validate the indirect examination and to assist in the development of an external corrosion model.

2.2 Scope of Work

Marr Associates personnel were retained to conduct the direct examination of the pipeline system. On-site analysis of the environmental, coating, and pipe conditions were performed to provide an overall assessment of the dynamics influencing the pipeline's integrity.

2.3 Report Format

The following sections of this report contain:

- A detailed explanation of the methodologies used in each excavation;
- An overall analysis of this project explaining relationships between the discovered features, pipeline and terrain conditions, and other factors; and
- A summary for each excavation consisting of a text summary, site diagrams, PIMS report, and site photos.

3.0 Methodology

The standard investigative program consists of these major tasks:

- Determining program objectives;
- Selection of the investigative sites completed by the client;
- On-site data collection and documentation associated with each site;
- Determination of coating conditions;
- The non-destructive examination, evaluation, and documentation of the pipe to confirm the presence, extent, and severity of external and internal integrity threats;
- Completing any necessary engineering assessment for each integrity concern detected;
- Application of a suitable replacement coating;
- Integration of field-collected data to the integrity management plan;
- Analysis and modification of the integrity management plan; and
- Review of the integrity management plan and correlation to existing regulatory codes and policies.

3.1 Investigative Site Selection

Investigative sites are selected by analyzing all available data for the pipeline segment being studied. This data may include:

- Indirect surveys;
- Soil survey data;
- In-Line Inspection (ILI) data;
- Coating survey data;
- As-built and construction diagrams;
- Manufacturing reports;
- Cathodic Protection (CP), Close Interval Surveys (CIS), historical CP data, and identification of CP facilities; and
- Interviews with operation and maintenance personnel.

Marr Associates personnel visit each prospective site in the field to confirm site position, obtain Global Positioning System (GPS) co-ordinates, and document surface features.

3.2 On-Site Data Collection

Marr Associates has a standardized field procedure for the assessment and documentation of investigative sites. This procedure consists of:

- The description and documentation of terrain conditions;
- Measuring the depth of pipe;
- Assessment and documentation of the pipeline coating conditions;
- The identification and documentation of pipeline corrosion deposits;
- The documentation of pH values for electrolyte found beneath the disbonded coating;

- When possible, the collection of corrosion deposits, microbial samples, and electrolyte samples;
- Measuring the pipe-to-soil potential at pipe depth;
- Determining the existing surface profile of the exposed pipe;
- The non-destructive examination of the pipe for external and internal corrosion or other relevant surface indications that may be an integrity concern (i.e. hydrogen induced cracking [HIC], stress corrosion cracking [SCC], or third party contact damage);
- If external and internal corrosion is identified, the confirmation of depth;
- The documentation of all relevant defects;
- If necessary, the use of ultrasonic testing (UT) equipment to confirm the absence of metal due to external or internal corrosion of the pipe; and
- The use of UT to assess external and internal corrosion and or relevant surface indications during the development of ILI crack-detection technologies.

3.2.1 Terrain Analysis

At each investigative site, the terrain conditions are recorded as the pipeline is excavated. The documentation of terrain conditions includes the identification of soil type, drainage, and topography parameters.

3.2.2 Soil Type

The soil type classified at each investigative site is based on the mode of deposition and texture. Table 3.1 below lists the various soil environment descriptions:

Table 3.1: Soil Type Classifications

Soil Type	Description
Glaciofluvial/Fluvial	Sorted and stratified, sandy and/or gravel-textured material, which includes alluvial sand and gravel derived from relict watercourses.
Till (Morainal)	Variable soil texture with a variable-size range of unsorted stones. Includes gravel, sand, clay, and silt that were glacial in origin.
Lacustrine	Typically fine-textured deposits, clay to silt, with well-defined stratification. Deposits are typically formed in standing bodies of water.
Alluvial	Commonly cobbles, gravel and sand-textured sediments that are stream-derived and are highly variable concerning stratification.
Eolian	Wind-derived material, usually fine to very fine textured sands.
Organic	Partially to wholly decomposed organic material.

3.2.3 Soil Drainage

The soil drainage is determined at pipe level based on soil characteristics such as depth of mottling and gleying or the absence of soil drainage impediments from the soil surface. Listed below are the definitions of drainage classifications identified at each site:

Table 3.2: Soil Drainage Classifications

Drainage Type	Description
Well Drained (W)	Oxidizing environment throughout the year.
Imperfectly Drained (I)	Alternating oxidizing and reducing environment. The environment is dependent on the fluctuation and amount of soil moisture.
Poorly Drained (P)	Primarily reducing conditions. The environment may be saturated throughout most of the season.
Very Poorly Drained (VP)	Reducing conditions throughout the entire year. The environment is saturated year-round. (i.e. anaerobic)
Very Poorly – Very Poorly Drained (VP-VP)	Reducing conditions throughout the entire year. The soil consists of organic material and the environment is saturated year-round. Standing bodies of water are present on surface topography.

A number of factors can help determine the drainage of the soil. They are:

- Presence of an organic layer;
- Water table depth;
- Presence, abundance, and depth of mottles in the mineral soil;
- Presence and depth of gley colors in the mineral soil; and
- Delineation of recharge and discharge areas.

The presence of a layer of organics on top of the mineral soil is indicative of the soil's drainage. A layer of 16 in. or more of organics indicates a very poorly drained soil.

Seasonal changes in the water table need to be considered when determining drainage. For example, if the water table depth is above the top of the pipe throughout the year in a mineral soil, the drainage can be classified as very poor.

Mottling of the soil appears as blotches or spots of a different color or shade of color generally yellow to red hues than the main soil color. Mottled soils are indicative of a fluctuating water table, which produces alternating reducing and oxidizing conditions, and are mainly associated with imperfect or poorly drained soils.

Gleying of the soil appears as a grey to blue or green color within the soil matrix. Gleyed soils are indicative of saturated or reducing conditions throughout the year, and are mainly associated with poorly or very poorly drained soils.

Under different hydrological situations, the soil profile does not need to exhibit mottling or gleying if the drainage is imperfect, poor, or very poor. This can be found in localized or regional discharge groundwater.

3.2.4 Topography

The topography at each site is documented according to the landscape pattern. Listed below are the topography and site position classifications used during each investigative program:

Table 3.3: Topography Classifications

Topography	Description
Undulating (U)	Regular sequence of gentle slopes from alternating concave and convex patterns.
Ridged (R)	Sharp crested or dome shaped.
Inclined (I)	Sloping surface.
Level (L)	Flat to very gently inclined.
Depressed (D)	Topographically low-lying area.
Side Slope (S)	Side slope of an incline, perpendicular to the pipeline right-of-way.

3.2.5 Site Position on a Slope

The location of the site was identified with respect to local topography according to the following criteria:

Table 3.4: Site Position Classifications

Site Position	Description
Crest	The uppermost portion or apex of a slope.
Upper Slope	The uppermost portion of a slope immediately below the crest.
Middle Slope	The area between the upper and lower slope.
Lower Slope	The lower portion of the slope immediately above the toe.
Toe	The lowermost portion of the slope.
Depression	Any area that is concave in all directions.
Level	Any level area.

3.2.6 Carbonates

The presence or absence of carbonates (CO_3^{2-}) within a soil profile is indicative of the carbon dioxide (CO_2) levels in the pipeline environment. Near neutral pH stress corrosion cracking (SCC) has been associated with soils with higher levels of CO_2 , which forms carbonic acid, a weak acid within the pipeline environment.

3.2.7 Coating Assessment

After the pipe is excavated, the pipeline coating condition is inspected and documented at each investigative site. In most cases, the furthest upstream girth weld is located to provide a reference point and all subsequent measurements are referenced to it. This girth weld is referred to as the reference girth weld (RGW), and is located between joint AA (upstream) and joint A (downstream). Personnel from Marr Associates identify and document the longseam (or other weld type) and girth weld positions at each site.

On a joint-by-joint basis, the coating condition is identified and documented. The coating conditions that are documented include areas that are well bonded, areas of disbondment, tented regions across welds, and locations of holidays. Below, Table 3.5 outlines the general definitions used to qualitatively characterize pipeline coating conditions:

Table 3.5: Qualitative Condition Descriptions

Coating Condition	Description of Disbonded Coating	Common Corrosion Deposits Pattern
Excellent	Very good adhesion; continuous thickness; <1% disbondment; occasional holidays.	None
Good	1 to 10% disbondment; scattered holidays; good adhesion.	Spotty
Fair	10 to 50% disbondment; scattered to numerous holidays; random areas of poor adhesion.	Spotty to Intermittent
Poor	50 to 80% disbondment; numerous holidays; multiple or long areas of poor adhesion.	Intermittent to Continuous
Very Poor	>80% to total disbondment; numerous holidays; no adhesion, brittle coating.	Continuous to Dense

The description of the coating condition is correlated to the terrain conditions on a per-joint basis, allowing Marr Associates to determine the probability of similar coating conditions throughout a pipeline system.

3.2.8 Corrosion Deposits and Electrolytes

Upon removal of the coating, the presence or absence of corrosion deposits is noted. Documentation of the corrosion deposits includes the color, texture, and distribution. These physical properties assist with identification of the corrosion deposits in the field.

Marr Associates has found that common corrosion deposits found beneath pipeline coatings can include:

- White, pasty iron carbonate (FeCO_3) - anaerobic, strong association with SCC, cathodic shielding and external corrosion;
- White, powdery calcium carbonate (CaCO_3) - indicative of a functioning CP system;
- Black, metallic/hard/pasty/powdery iron sulfide (FeS) - indicative of the presence of sulfate reducing bacteria (SRB); and

- Orange/grey, powdery/scaly/film iron hydroxides and oxides (FeO , Fe_3O_4 , FeO/OH) consisting of magnetite, maghemite, goethite, and lepidocrocite - variable aerobic/anaerobic conditions.

In order to properly assess an investigative site and its relationship to environmental conditions and integrity concerns, it is necessary to correctly identify corrosion deposits and the pH of the electrolyte beneath the disbonded coating. When combined with other specific environmental parameters, certain corrosion deposits are indicative of either the presence or absence of SCC, external wall loss, and microbial induced corrosion.

In the event that electrolyte is present between the surface of the pipe and coating, its location and properties are recorded. Electrolyte color is recorded and electrolyte pH is visually measured using pH litmus paper. Non-classical SCC is commonly associated with an electrolyte pH reading between 6.0 and 8.5; classical SCC is known to be associated with an electrolyte pH range between 9.0 and 11.0. SCC is not known to occur when the electrolyte pH is greater than 11.0.

If the presence of bacteria is suspected, corrosion deposit samples are collected and analyzed by population density, general bacteria type (SRB or APB), and by-product type (i.e. type of organic acid).

3.3 Pipe-to-Soil Reading

A voltmeter and a Cu/CuSO_4 electrode are used during an investigative excavation to obtain CP readings at the 12:00, 3:00, 6:00, and 9:00 o'clock pipe positions at regular intervals along the pipeline. For short excavations, the readings will be taken at the upstream and downstream ends of the excavation. These readings will show whether the CP is reaching all areas of the pipeline or if there is any CP drop over the length of the excavation.

3.4 Corrosion Feature Assessment

To accurately document an external corrosion feature, a reference point is defined as the upper left corner of the feature. This reference location is defined as the distance from the girth weld and the circumferential distance from the top of the pipe. The overall axial and circumferential lengths of the feature are recorded. The corrosion feature is then prepared for mapping by superimposing a grid over the entire anomaly area. The grid size utilized is dependant on client preference, but typically, a 0.5 in. or 1.0 in. grid is used to delineate the corrosion feature area. UT techniques or mechanical gauges are used to obtain the remaining wall thickness readings or pit depths at each grid reference node, both axially and horizontally along the pipe. The readings are recorded in a spreadsheet.

A pit depth gauge is used to map the depths of small corrosion features. The two edges of the pit gauge, which extend out 2 inches on either side, must be positioned on uncorroded pipe in order to obtain an accurate pit gauge reading. This procedure allows the corrosion depth to be assessed in reference to the original outside diameter of the pipe. In the event that the corrosion feature is extensive, a bridging bar is required in order to obtain representative readings. The bridging bar is positioned on the pipe so that measurements are calibrated from a flat surface.

UT pencil probe measurements are made using a 1/4 in. ultrasonic transducer with a conical delay line of 1/8 in. diameter at the tip. Pencil probes measure the remaining wall thickness, while the pit gauge measures the corrosion depth. The pencil probe method is more versatile than the pit gauge technique because it is not limited by the requirement of a flat, uncorroded pipe surface to bridge the pit gauge across.

4.0 Results and Analysis

Marr Associates was contracted by PRCI to collect soil survey and direct examination data for the development of an external corrosion direct assessment (ECDA) corrosion model. Other third party contractors were retained to perform indirect ECDA surveys on the pipeline owned by Operator E. Marr Associates personnel were retained to perform a soil survey and to conduct the direct examination of the pipeline. After Operator E determined the areas of concern on the pipeline system using ECDA diagnostic surveys, two locations were selected for direct examination. Marr Associates field personnel worked under the direction of Operator E personnel.

4.1 Background

The Operator E pipeline system was constructed in 1950 and has an outside diameter (O.D.) of 16 in. The pipeline was manufactured from Youngstown, X46 grade line pipe and has an ERW longseam. The nominal wall thickness of the pipe is 0.250 in. The pipeline was coated with factory-applied asphalt, fusion bond epoxy (FBE), field-applied mastic, and tape-single wrap.

4.2 Excavation Investigation

The field investigation took place at two selected sites on Line G. The sites were chosen based upon results from ECDA methods. In particular, the excavation revealed external corrosion at Site 1 and a bare tap and two stopples at Site 2.

Four partial joints and two girth welds totaling 41 ft 6.0 in. of pipe was excavated and inspected for coating defects. All sites were inspected for the presence of external corrosion and other relevant surface indications. Disbonded coating from the pipe surface was removed for a total of 23 ft 6.6 in. to facilitate inspection for pipe defects and external corrosion. Two external corrosion features were found on the pipeline at Site 1.

4.3 External Corrosion Soil Model

The terrain description of an excavation site is one of the components used in the development of an External Corrosion Soil Model. The terrain study includes information about the soil composition, topography and drainage. The description of the soil environment is used to delineate those areas of a pipeline that are situated in environments conducive to significant external corrosion. The reliability and validity of an External Corrosion Soil Model is based upon extensive investigative excavations, and the model assumes that the coating may be disbonded in susceptible areas. An External Corrosion Soil Model is developed by combining the results of a terrain study with information about pipeline materials, coating, construction and maintenance information.

Specific terrain combinations, indirect survey information and coating type are the major determinants of whether the environment may cause external corrosion on the pipe surface. Defining the terrain conditions and measuring the CP potential are the initial steps in evaluating a site's potential for developing external corrosion. The two components alone do not determine susceptibility of the pipeline, but can assist in validating soil model development.

One step in the development of an external corrosion soil model will be determining the extent to which existing models developed for locating stress corrosion cracking (SCC) are applicable to an external corrosion model. Marr Associates has extensive experience with developing soil models for the presence of SCC, an environmentally assisted type of cracking which can be related to the presence of external corrosion.

4.4 Coating Condition

The pipeline was coated with factory-applied asphalt at Site 1, and was in excellent to fair condition. Site 2 was coated with factory-applied asphalt, FBE, field-applied shrink sleeves, single-wrap tape, and mastic. The condition of the coating at this site was in excellent to good condition. A bare tap and two bare stopples were also located in Site 2. Minor disbondment of the coating at both sites was due to soil stress on the pipe.

4.5 Terrain Results

Both sites were located in a floodplain region. The topography at the sites was level. The soil type was characterized to be fluvial silt mixed with clay and very fine sands. The drainage at Site 1 was imperfect to poor. Gleying of the soil occurred from 39.4 in. to the depth of excavation, encasing the pipeline. Groundwater seepage occurred at 61.0 in. below the ground surface. The soil at Site 2 was well drained. Site 2 was located adjacent to a concrete drainage canal.

4.6 Soil Resistivity

The soil resistivity gives an indication of the ability of the soil to carry the cathodic protection (CP) current to the pipeline. The soil resistivity is inversely proportional to the soil conductivity; therefore CP current does not carry as well through a soil associated with a higher resistivity.

Soil type and drainage are also associated with soil resistivity values. The ability of soil to conduct current increases when water is contained within the soil pores. Soil pore size and cohesion are soil characteristics that can affect the rate of water percolating through and retained in the soil matrix. Soils with dominant clay textures, which have smaller pore spaces and good cohesion can retain water longer than sand and gravel, which have larger pore spaces. Consequently soil resistivity is reduced and the CP system is more efficient in wetter soils. For this investigation, the presence of finer soils (a dominant silt soil mixed with clay) at both sites can partially account for the relatively low resistivity values.

The moisture present at both sites also partially accounts for the low resistivity values. As mentioned earlier, the soil type at both sites was the same. Site 1 clearly indicates the presence of stagnant water in that the soil was gleyed, the drainage was imperfect to poor, and there was groundwater seepage. Though the drainage at Site 2 was well, it was located beside a drainage canal, which may account for high levels of water movement around the pipeline.

Table 4.1 presents the resistivities obtained during this investigation:

Table 4.1: Resistivity Summary

Site Name	Resistivity (Ω -cm)
Site 1	840
Site 2	930

The soil resistivity also indicates the relative aggressivity of the soil in promoting galvanic corrosion. Table 4.2 illustrates the relationship of soil resistivity with the soil corrosivity.

The following table is taken from *NACE Corrosion Basics*:

Table 4.2: Soil Resistivity vs. Degree of Corrositivity

Soil Resistivity (Ω -cm)	Degree of Corrositivity
0 - 500	Very corrosive
500 - 1,000	Corrosive
1,000 - 2,000	Moderately corrosive
2,000 - 10,000	Mildly corrosive
Above 10,000	Progressively less corrosive

The soil resistivity seen in this investigation indicates a corrosive environment at both sites. The soil characteristics described above contribute to this environment. As well, the soil pH at both sites was slightly acidic, which is another indication of the corrosive environment.

Table 4.3 presents the pH values obtained during this investigation:

Table 4.3: pH Summary

Site Name	pH
Site 1	6.34
Site 2	6.45

4.7 Cathodic Protection

The CP values for "on" potential were obtained utilizing a saturated copper sulphate reference electrode. CP "on" measurements were taken at the upstream end of each excavation. The following table summarizes the CP values at all of the sites investigated:

Table 4.4: CP "On" Values

Site Name	Upstream CP "On" (volts)	Downstream CP "On" (volts)	Average CP "On" (volts)
Site 1	-1.096	-1.177	-1.137
Site 2	-1.329	-1.335	-1.332

All the CP readings taken exceed the industry criterion of -0.850 volts "on". A rectifier was located at Site 1. It was out of service due to damaged cables.

4.8 Corrosion Deposits

A variety of corrosion deposits were found at all of the sites during this program. Table 4.4 illustrates the coating conditions, type of disbondment with possible cause, and the corrosion deposits found under the disbonded coating at each site.

Table 4.4: Corrosion Deposits under the Coal Tar Disbonded Coating

Site Name	General Coating Conditions	Type of Disbondment	Type of Corrosion Deposits Pattern - Texture - Type
Site 1	Joint AA – Fair, Joint A - Excellent	Soil Stress - Poor Adhesion	Spotty - Scaly - FeO/OH Intermittent – Pasty – FeCO ₃ Intermittent - Film - CaCO ₃ ,
Site 2	Joint AA - FBE – excellent, Joint AA/A GW – Shrink sleeve - good Tape – good to excellent Mastic – good Asphalt - excellent	Soil Stress - Poor Adhesion	Dense, Intermittent - Scaly - FeO/OH Spotty - Powdery - CaCO ₃

Dense, spotty and intermittent deposits of CaCO₃ and FeO/OH were found at most of the disbonded coating locations. Intermittent deposits of FeCO₃ occurred only at Site 1. The occurrence of FeCO₃ at Site 1 may indicate temporary reducing anaerobic conditions around the pipeline. Disbonded areas with the presence of CaCO₃ on the pipe surface and a lack of external corrosion can be an indication of a functioning CP system at these areas.

4.9 Conclusion

Four partial joints and two girth welds totaling 41 ft 6.0 in. of pipe were excavated and inspected for coating defects. All sites were inspected for the presence of external corrosion and other relevant surface indications. Disbonded coating from the pipe surface was removed for a total of 23 ft 6.6 in. to facilitate inspection for pipe defects. Two external corrosion features were found on the pipeline at Site 1.

The soil type was classified as fluvial silt, mixed with clay and very fine sand. The resistivity range was from 840 Ohm-cm to 930 Ohm-cm. The low resistivity values categorize the soils as corrosive. Factors contributing to these low values include the soil particle size and moisture. The soil type was dominated by silt and included clay, facilitating the retention of moisture. This has been shown to increase the efficiency of the cathodic protection system as a result of enhanced current conduction in a moist environment. For this investigation, the CP measurements taken at both sites exceeded the industry criterion.

With regards to moisture, the sites were located in a floodplain region; therefore the area may have experienced flooding throughout its history. When experiencing increased moisture conditions (such as rainfall), surface water may tend to pool and move quickly to drainage outlets. Sections of pipelines located near or in small depressions such as the drainage canal located next to Site 2, may be exposed to a more dynamic electrochemical environment. The drainage at Site 1 was imperfect, and experienced groundwater seepage. Site 2 was well drained.

The asphalt coating at Site 1 varied from excellent to fair condition. Site 2 had multiple coatings including a shrink sleeve, mastic, FBE, and single wrap tape varying in excellent to good condition. Calcium carbonate and iron oxide/ hydroxide corrosion deposits were found on the pipe at most of the disbonded locations. The presence of gleyed soils encasing the pipeline at Site 1 indicates that it was exposed to saturated or reducing conditions throughout the year. This statement is further supported in that the anaerobic iron carbonate deposit was found only at this site.

5.1 Operator E: Site 1

This pipeline is located in the state of Louisiana. As part of an ECDA process, this site was selected by Operator E for excavation and direct examination. Marr Associates was contracted by PRCI to perform the direct examination of the pipeline at this site and collect data for the development of an ECDA corrosion model. Marr Associates field personnel worked under the direction of personnel from Operator E. This report details the results of the direct examination of the pipe at this location.

This excavation consisted of two partially exposed joints and one girth weld, totaling 23 ft 9.6 in. The reference girth weld (RGW) was located 22 ft 6.0 in. from the upstream end of the excavation. The soil surrounding the pipe was partially removed to permit examination of the pipe. Refer to the Site Overview for a schematic representation of the excavation.

Table 1 summarizes the pipe and coating at this location:

Table 1: Pipe and Coating

Pipe Manufacturer	Youngstown
Pipe Grade	X46
Outside Diameter	16 in.
Nominal Wall Thickness	0.250 in.
Weld Seam and Type	ERW
Coating	Factory-applied Asphalt
Date Pipe Buried	1950

The topography and site position were level at this location. The soil consisted of imperfect to poorly drained fluvial silt shown in Photo 1. Gleying of the soil occurred from 29.5 in. to the depth of the excavation. Ground water seepage occurred within the excavation at 61.0 in below the ground surface. Ground water was also observed seeping at the pipe location, 49.5 in. below ground surface. No carbonates were present in the excavation.

Pipe-to-soil cathodic protection (CP) "on" readings were taken at the upstream and downstream ends of the excavation. The CP readings were measured by a saturated copper/copper sulfate reference electrode. A rectifier was located at the excavation site. The CP system was on, but the rectifier was off-line. Soil resistivity readings were taken at the excavation with a soil box. The pH readings were obtained by a field probe. Soil samples were collected at the excavation site and will be reported on at a later date.



Photo 1: Fluvial Silt Soil Profile

Table 2 summarizes the environment and measurements taken at the site:

Table 2: Site Conditions

Topography	Level
Excavation Position	Level
Soil Texture	Fluvial Silt
Drainage	Imperfect to Poor Mottling: None Gleying: From 29.5 in. to Depth of Excavation
CP Values	Upstream "on": -1.096 volts Downstream "on": -1.177 volts
Resistivity	840 Ohm-cm
Soil pH	6.33

After the pipe was exposed, the coating was examined for general condition and disbondments. At the direction of personnel from Operator E, the coating was then removed on joint AA to accommodate corrosion documentation, exposing the steel surface of the pipe at the disbonded coating locations. The coating damage was caused by soil stress.

Table 3 summarizes the details of the coating inspection and corrosion deposits:

Table 3: Coating and Corrosion Deposits

Soil Removed from Pipe	Joint AA: From 0 ft 0 in. to 22 ft 5.8 in. U/S of the RGW for 360 Degrees Joint A: From 0 ft 0 in. to 1 ft 3.6 in. D/S of the RGW from 12:00 o'clock to 3:00 o'clock Total Length of Uncovered Pipe: 23 ft 9.4 in.
Coating Inspected	Joint AA: From 11 ft 1.1 in to 22 ft 5.8 in. U/S of the RGW for 360 degrees Total Length of Coating Inspected: 11 ft 4.7 in.
Coating Condition	Joint AA: Fair Joint A: Excellent
Coating Removed	Joint AA: From 11 ft 1.1 in to 22 ft 5.8 in. U/S of the RGW for 360 degrees Total Length of Coating Removed: 11 ft 4.7 in.
Corrosion Deposits	Spotty deposits of scaly, orange FeO/OH Intermittent deposits of filmy, white CaCO ₃ Intermittent deposits of pasty, white FeCO ₃
Electrolyte (pH Value)	7.0

Photos 2 and 3 show the coating conditions and typical corrosion deposits:



Photo 2: Coating Conditions



Photo 3: Typical Corrosion Deposits

Two anomalies listed in the CPIG tool log were correlated in the field as two external corrosion features. A third party company used a pit gauge to determine the depths of the external corrosion features. An engineering assessment utilizing ASME B31G was performed by Operator E personnel. The two external corrosion features passed the engineering assessment and were blasted and recoated under the directions of Operator E personnel.

Table 4 presents a summary of the results of the pipe surface inspection:

Table 4: Pipe Surface Inspection

Length and Areas Inspected	No magnetic particle inspection (MPI) was performed at this site.
Number of Features	2; External Corrosion features determined by a Third Party Contractor

Note: The measurements locate the mid-points of the features

Photo 4 shows the Feature 3614:

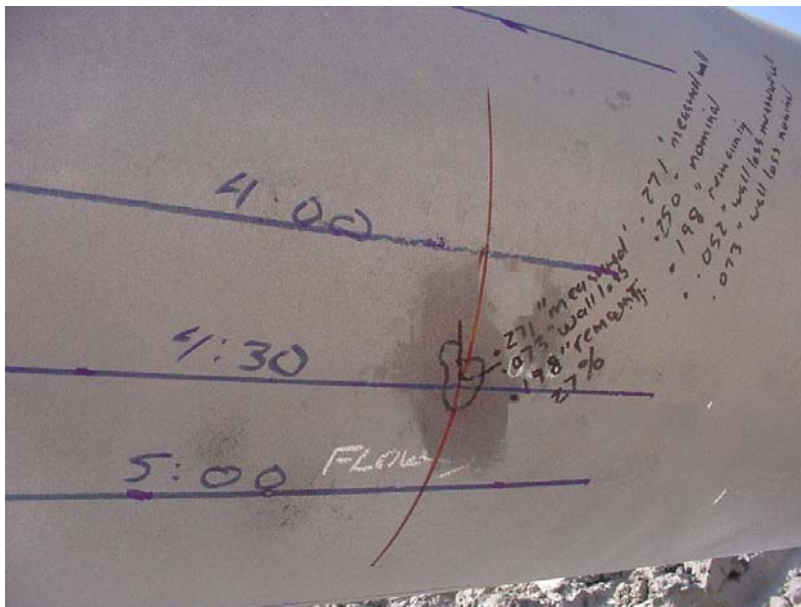


Photo 4: Feature 3614

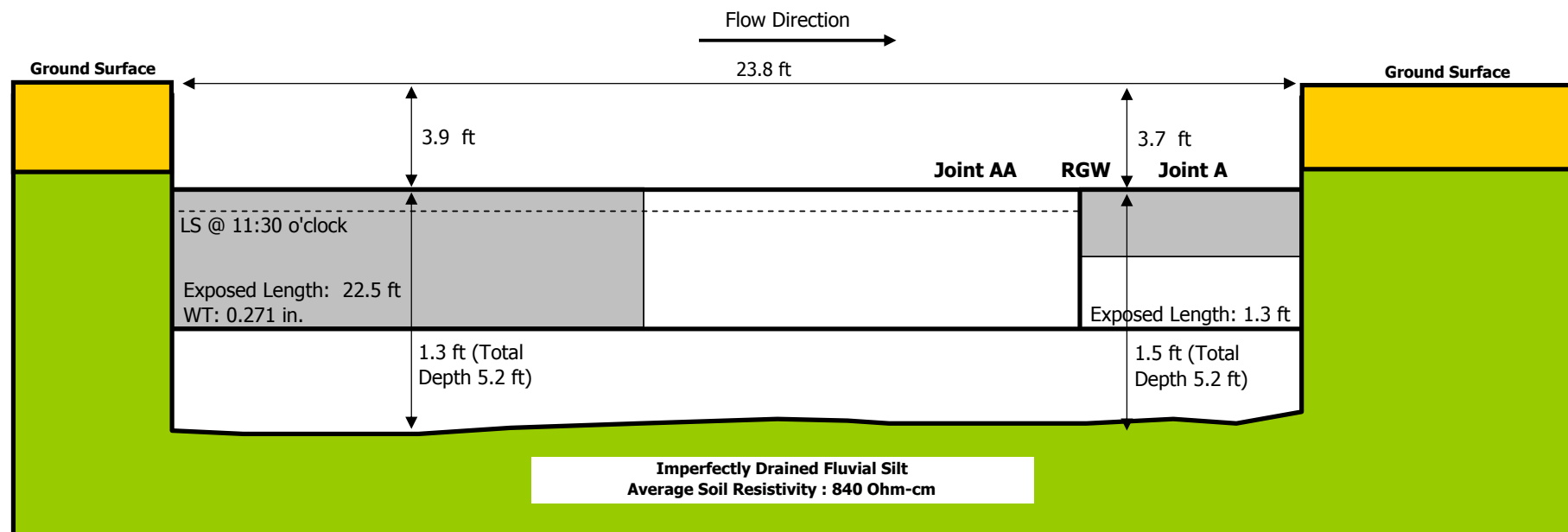
The pipe surface where coating was removed was recoated with RD6 Mesh Tape. Following the completion of the investigation, the pipeline was deemed safe and reliable for continued service by Operator E personnel.

Site Overview Operator E: Site 1

Site Chainage : Not Reported
Reference Point : Not Reported
Line : Line G

Excavation Depth : 5.2 ft
Pipe Depth : 3.7 ft, 3.9 ft
Excavation Length : 23.8 ft
Land Use : Commercial/Residential
Topography and Site Position : Level/Level

Nominal Wall Thickness : 0.250 in.
Pipe Diameter : 16 in.
Coating Type : Asphalt
Manufacturer : Youngstown
Longseam Type : ERW
Product : Natural Gas



Note: Dashed lines represent the counter clockwise side of the pipe.

Legend:

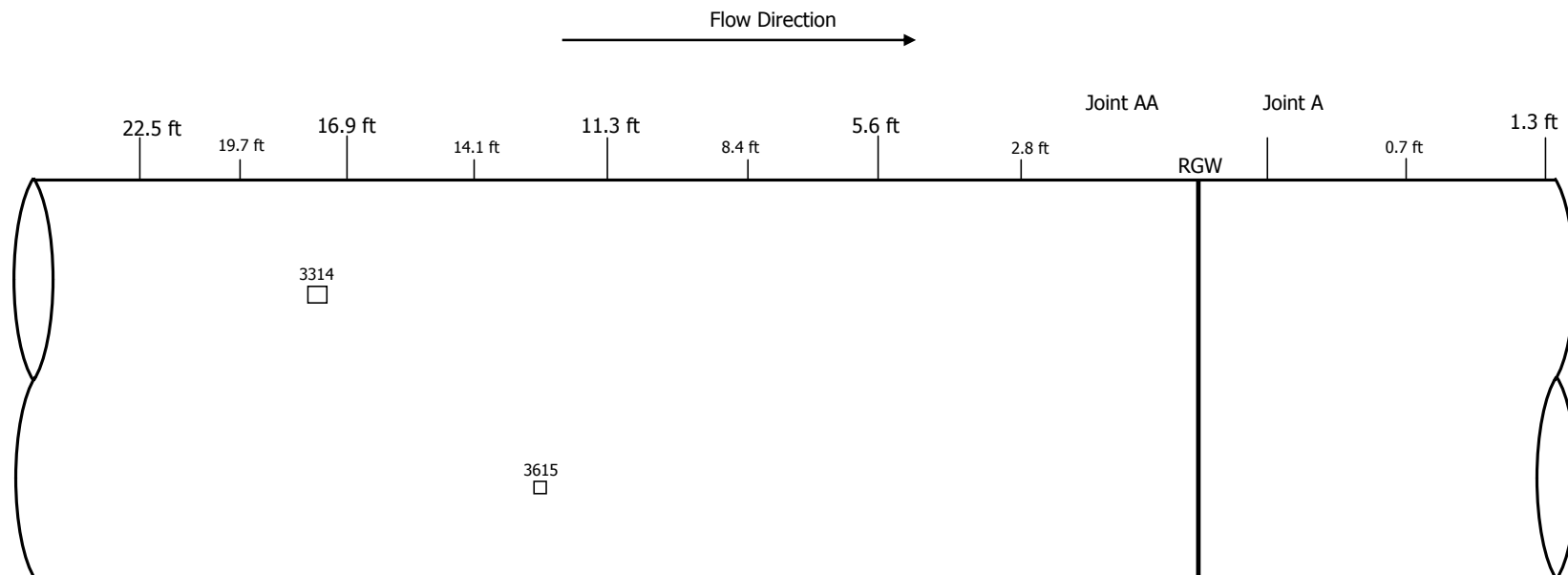
 Soil	 Exposed Pipe Surface
 Gleying	 Coating Not Removed

Field-identified Feature Summary

Site Chainage : Not Reported
Reference Point : Not Reported
Line : Line G

Site Name : Site 1
Number of Features : 2

Joint ID : AA
Measured Wall Thickness : 0.250 in.
Pipe Diameter : 16 in.
Field Personnel : D. Venance



Note: The dashed line represents the counter clockwise side of pipe
Figure is Representative Only - Not to Scale

Feature Identification	From (ft)	To (ft)	By (in.)	At (in.)	Clock Pipe Position	Length (in.)	Depth (%)
External Corrosion	17.0	17.1	1.0	18.7 CW	1:55	1.2	26.9
External Corrosion	13.62	13.65	0.2	8.1 CW	4:30	0.4	33.9

Note: Measurements performed by a third party contractor.

TABLE 1: SITE SUMMARY

Client :	PRCI
Excavation Name :	Site 1
Line :	Line G
Type of Investigation :	ECDA Validation Program
Total Length of Excavation :	23 ft 9.6 in.
Reference Point :	Not Reported
Chainage from Ref Pt. to RGW :	NA
Access :	Private; NA
Longseam :	ERW
Pipe Diameter :	16 in.
Nominal Wall Thickness :	0.25 in.
Coating Type :	Asphalt
Topography :	Level
Site Position :	Level
Soil Type :	Fluvial - Dominant Silt
Drainage :	Imperfect - Poor
Coating Conditions :	Asphalt - Fair
Documented Corrosion Precipitate(s) :	CaCO ₃ , Fe-oxide/hydroxide, FeCO ₃
Field pH Range :	7
SCC Detected (Yes or No) :	No



General Site Overview

General Terrain Conditions

Physiographic Boundary : Coastal

Vegetative Legend : Coastal

Soils Summary

From	To	From Depth	To Depth	Soil Type (Dominant)	Topography	Drainage
-1 ft 0 in	0 ft 0 in	0 in	54.7 in	Fluvial (Silt)	Level	Well
0 ft 0 in	16 ft 8.4 in	0 in	50 in	Fluvial (Silt)	Level	Well

Pipe Summary

Joint ID	Pipe Length	Measured Wall Thickness	Longseam Type	Joint (Completely) Buried
AA	1 ft 0 in.	0.264 in	ERW	No
A	16 ft 8.4 in.	0.271 in	ERW	No

Coating Summary

Joint ID	Coating Type	From	To	Coating Conditions	Wrinkling And Disbondments	Tenting Pattern
AA	Shrink Sleeves	0 ft 0 in.	0 ft 0.8 in.	Good	Minor	Spotty
AA	Fusion Bond Epoxy	0 ft 0.8 in.	0 ft 11.8 in.	Excellent	Well Bonded	None
A	Asphalt	16 ft 3.1 in.	16 ft 8.4 in.	Excellent	Well Bonded	None
A	Tape - Single	11 ft 0.7 in.	13 ft 9.2 in.	Excellent	Well Bonded	None
A	Mastic	13 ft 9.2 in.	15 ft 9.2 in.	NA	NA	None
A	Tape - Single	15 ft 9.2 in.	16 ft 3.1 in.	Excellent	Well Bonded	None
A	Shrink Sleeves	0 ft 0 in.	0 ft 11.2 in.	Good	Minor	Spotty
A	Tape - Single	0 ft 11.2 in.	8 ft 6.8 in.	Good	Minor	None
A	Mastic	8 ft 6.8 in.	11 ft 0.7 in.	Good	Well Bonded	Spotty

pH Summary

NA

Corrosion Deposit Summary

Type	Pattern	Number of Deposits
CaCO ₃	Spotty	1
Fe-oxide/hydroxide	Dense	1
Fe-oxide/hydroxide	Intermittent	1

Additional Notes

During the field investigation, Marr Associates identified a bare stopple fitting was at the ECDA feature location. No external corrosion features were found at the time of inspection. The pipe surface where coating was removed was recoated with RD6 mesh Tape, and Enviroline EC 124. Following the completion of the investigation, the pipeline was deemed safe and reliable for continued service by Operator E personnel.

Corrosion Deposit Assessment

Joint ID: A

Fe-oxide/hydroxide

